Risk Assessment

Argentine Beef

Animal and Plant Health Inspection Service
United States Department of Agriculture
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ARGENTINE BEEF RISK ASSESSMENT

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INTRODUCTION

The purpose of this document is to assess the probability that beef exported from Argentina as allowed by APHIS's Final Rule, CFR 94.21, would be contaminated with foot-and-mouth disease (FMD) virus.

This document answers the question, "What is the probability that fresh, chilled, or frozen beef imported from Argentina according to the requirements specified in the Final Rule and other existing USDA regulations regarding imported beef will be contaminated with FMD?" The analysis assumes that beef exported in full compliance with CFR 94.21 will have a negligible risk of contamination with FMD virus. The document evaluates the probability that fresh, chilled, or frozen beef exported in response to the Final Rule but not in full compliance with certain requirements of the Rule will be contaminated with FMD.

The assessment begins by identifying three "un-planned" risk pathways linking an initiating activity --cattle slaughtered for export-- to an adverse outcome --the export of FMD contaminated beef. These pathways are identified and are shown diagrammatically in a scenario tree (Figure 1). The pathways are: 1) Beef which was not maturated to pH 5.8 and not diverted to domestic Argentine use; 2) Beef from which lymph nodes, bones, and/or blood clots were not completely removed; and 3) Beef from which lymph nodes, bones, and/or blood clots were not completely removed and which was not maturated to pH 5.8 and not diverted for domestic use in Argentina. Beef exported in full compliance with CFR 94.21 follows the "as-planned" pathways in the scenario tree.

Other unplanned pathways are possible and with some creativity and imagination, perhaps several dozen unplanned pathways could be identified. Time and resource limitations do not permit the evaluation of every conceivable unplanned risk pathway. The three unplanned pathways evaluated in this assessment were selected because in the authors' opinion, they represent the most probable sources of disease risk.

The next step in the assessment requires assigning quantitative probability values to each branch point in the pathways. As much as was possible, values were assigned based on factual evidence and the evidence is listed and referenced. Ideally, values should be based on the results of specific, focused, replicated research results and surveillance data. However, such results and data are rarely, if ever, available for risk assessment, and the use of subjective, expert judgement is necessary. This is as true for this risk assessment as it is for every risk assessment.

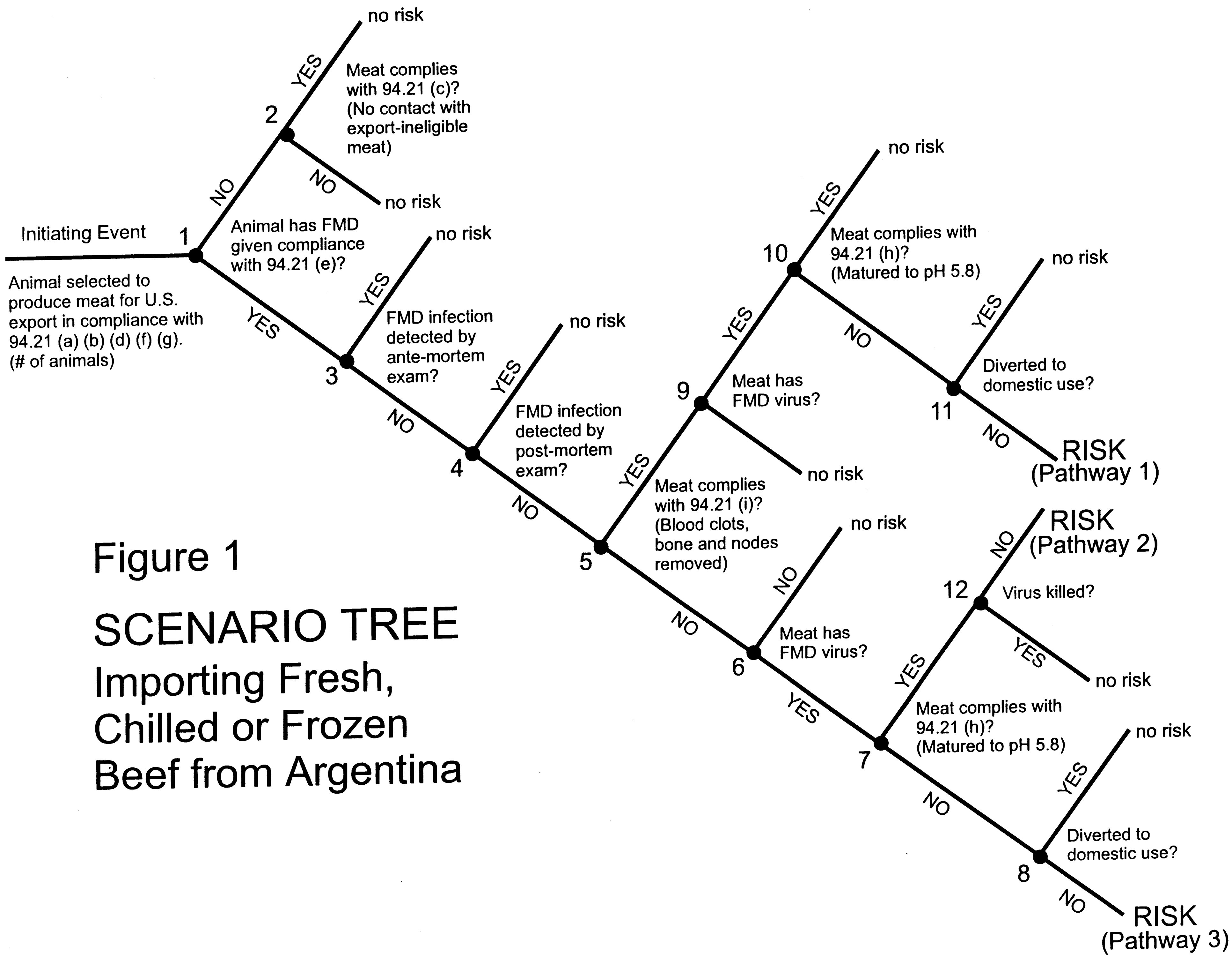


Figure 1

SCENARIO TREE
Importing Fresh, Chilled or Frozen Beef from Argentina

Finally, a mathematical model was developed based on the scenario tree. Using this model and the quantitative values for each branch point, the probability that imported beef would be contaminated was calculated. The results are expressed as the probability that any given side of beef would be contaminated and as the probability of importing one or more contaminated sides of beef per year.

Uncertainty in branch point values is unavoidable. The assessment uses probability distribution functions to address uncertainty. @Risk software (Palisade Corporation) was used to multiply distributions.

All probability values in this risk assessment are conditional on the branch points in the pathways preceding a given branch point. Thus, for example, the probability of detecting a FMD-infected animal during post-mortem exam of the carcass (branch point 4) is conditional on the animal complying with 84.21 (a)(b)(d)(f)(g), having FMD, and not being detected by ante-mortem exam (branch points 1 and 3).

Risk assessments are only as good as the quality of information used to perform them. Risk assessment is a dynamic process, i.e., the results can change as better, more complete information is obtained. Readers with specific factual information relevant to the branch point values in this assessment are encouraged to make such information available to APHIS.

The prevalence of FMD in South America will probably decrease with time as a consequence of the Pan American Health Organization's FMD eradication activities. Thus, the probability that exported meat from any South American country, Argentina included, would introduce FMD to the United States should similarly decrease. U.S acceptance of South American beef provides an important incentive for South American countries to pursue FMD eradication. The resulting decreased probability of the introduction of the disease into the U.S. should be recognized as a significant benefit.

ASSUMPTIONS

By agreement between Argentina and the United States, imports of beef are limited to 20,000 metric tons per year. It is assumed that 20,000 metric tons per year will be imported. Depending on number of kilograms of beef exported per animal slaughtered, the number of cattle required to produce 20,000 metric tons can be calculated. If the amount of beef exported is greater or less than the 20,000 metric tons expected, the probability of FMD should change proportionally.

The International Organization for Epizootics (OIE) has recognized Argentina free of FMD with vaccination. This assessment assumes that Argentina's reports to OIE about FMD and the OIE's classification of Argentina are accurate and reflect the best information available concerning the prevalence of FMD in Argentina. Thus, there are only two ways in which an FMD-infected animal could be slaughtered and offered for export. First, undetected, asymptomatic chronic FMD carriers could exist within Argentina; second, FMD could be introduced into Argentina leading to an acute outbreak of disease.

This assessment assumes that acute outbreaks of FMD in Argentina would be detected and exports terminated before any FMD-infected animals could be slaughtered and the beef from those animals exported. Thus, the assessment will focus only on the probability that undetected FMD-infected chronic carrier animals are offered for slaughter and export.

It is assumed that if a chronic FMD-infected animal is slaughtered and the infection is not detected and the virus in the side(s) of beef is not inactivated or removed by processing, then all of the beef in the side(s) is FMD contaminated.

It is assumed that if FMD-contaminated meat is exported, the meat does not contaminate other meat in the same shipment. This assumption, combined with the previous assumption means that if a side of beef is FMD-contaminated, the entire side (but nothing else) is contaminated regardless of whether the contamination consists of only a single virus particle or a very large number of particles.

This assessment focuses on the probability of FMD-infected animals and contaminated sides. It is recognized however, that actual exports will consist of boneless cuts of beef. Note that the simple act of *cutting* a side of beef into boneless cuts should not affect the probability of FMD in exported product in contrast to the *removal* of bones (and lymph nodes and blood clots) which would be expected to affect the probability and which is required by the Final Rule and addressed in this assessment.

The assessment assumes that the probability of rinderpest in meat exported from Argentina is acceptably low and therefore this probability is not evaluated. Rinderpest has never been reported in Argentina or anywhere in the western hemisphere.

The impact on risk of clustered selection of animals from specified herds, from grass-fed versus grain-fed herds, and of herds within specified regions is not addressed. (See the economic analysis section of the Final Rule for discussion of the types of cuts that are expected to be exported.) It is noted that there is no available information indicating a difference in the prevalence of FMD in grain-fed versus grass-fed cattle in Argentina. The assessment assumes that animals selected for slaughter for export are randomly selected from the entire population of eligible Argentine cattle. The assumption is conservative and will overestimate FMD risk.

The assessment assumes that animals selected for slaughter for export comply with CFR 94.21 (a)(b)(d)(f)(g) of the Final Rule. These sections require that:

(a) The meat is beef that originated in Argentina

(b) The meat came from bovines that were moved directly from the premise of origin to the slaughterhouse without any contact with other animals;

(d) The meat came from bovines that originated from premises where foot-and-mouth disease and rinderpest have not been present during the lifetime of any bovines slaughtered for export of meat;

(f) The meat came from bovines that originated from premises on which ruminants or swine have not been vaccinated with modified or attenuated live viruses for foot-and-mouth disease at any time during the life of the bovines slaughtered for export of meat; and

(g) The meat came from bovines that have not been vaccinated for rinderpest at any time during the lifetime of any of the bovines slaughtered for export of meat.

Evidence justifying this assumption includes: 1) The use of modified live or attenuated FMD vaccine is illegal in Argentina; 2) The use of rinderpest vaccine is illegal in Argentina; 3) Rinderpest is a highly contagious disease which has never been reported in Argentina or anywhere in the western hemisphere; and 4) Argentina has been declared FMD free with vaccination by the OIE for FMD.

It is assumed that beef that is maturated to pH 5.8 and that does not contain lymph nodes, bones, and blood clots has negligible risk. Abundant research literature exists demonstrating that FMD virus does not survive in muscle tissue at pH 5.8 (Cottral et al, 1960).

Other assumptions pertaining to only a single branch point in the scenario tree will be addressed as part of the evidence for that branch point.

EVIDENCE

Initiating Event

The initiating event is the selection of animals for slaughter to produce beef for export to the United States. The initiating event is quantified as the number of animals per year selected.

IE-1 Beef cattle weigh approximately 350-450 kg or about 800-1000 pounds. After skinning, evisceration, and removal of the head and feet, a beef carcass weighs approximately 225 kg (495 lbs). (pers. comm., M. Garcia, APHIS-NCIE staff, 1997)

IE-2 APHIS's site visit team proposed in its Back-to-Office Report that 10 kg of beef per slaughtered animal be assumed for risk assessment purposes. (Metcalf and Blackwell, Back-to-Office Report, 1994).

IE-3 Two million cattle are required to produce 20,000 metric tons of beef if only 10 kg of beef is exported per animal slaughtered. (APHIS staff calculation)

IE-4 Some APHIS staff believe that the quantity of beef exported per animal slaughtered may be substantially more than 10 kg. The quantity exported per slaughtered animal is likely to increase with time as Argentine beef becomes more accepted in U.S. markets. (pers. comm., R. McDowell, APHIS-PPD staff, 1997)

IE-5 APHIS staff have no confidence that the quantity of meat exported per animal slaughtered would exceed 100 kg or 10 times the estimate in the Metcalf/Blackwell report. 200,000 cattle are required to produce 20,000 metric tons of meat if 100 kg of beef is exported per animal slaughtered. 400,000 cattle are required to produce 20,000 metric tons of meat if 50 kg of beef is exported per animal slaughtered. (APHIS staff estimate)

Branch Point 1

Branch point 1 is the probability that an animal going to slaughter has FMD, given that it is an Argentine-origin animal. This probability is designated f1.

1-1 Argentina has a cattle population of approximately 50 million animals. Close to 100% of these animals are eligible for slaughter for export. (Situation of the FMD Control Programs in South America, Pan American Health Organization, 1996)

1-2 The last reported outbreaks of FMD in Argentina occurred in April, 1994. Fifteen premises were affected with FMD type O and 2 premises with type C. (PAHO, 1996)

1-3 90% of cattle in Argentina are vaccinated with an inactivated FMD vaccine. Sheep, goats, and pigs in Argentina are not vaccinated for FMD and therefore serve as sentinel animals. (PAHO, 1996)

1-4 100% of the cattle in Argentina are under a national FMD surveillance program. (PAHO, 1996)

1-5 Argentina has been recognized by the OIE as free of FMD with vaccination. (OIE Meeting, Paris, 1997)

1-6 Given that Argentina has not had any reported outbreaks of FMD in over three years, that Argentina has a large population of susceptible pigs, sheep, goats, that 10% of the Argentine cattle population is not vaccinated, and that Argentina has effective national surveillance for FMD, it is assumed that the most likely number of chronic FMD carriers in Argentina is zero and the maximum possible number of chronic FMD carriers is 10. (APHIS staff estimate)

1-7 Given evidence 1-1 and 1-6, the maximum probability that a randomly selected animal in Argentina has undetected FMD is 10 divided by 50 million = 2 x 10E-7. (APHIS staff calculation)

Branch Point 2

Branch point 2 is the probability that the meat complies with 94.21 (c). 94.21 (c) requires that the meat has not come in contact with meat from countries other than those listed in CFR 94.1 (a) (2). This probability is designated f2.

It is theoretically possible that meat not in compliance with 94.1 (a) (2) could contaminate meat exported from Argentina. However, time and resources being limited, APHIS staff determined that this is a less important risk pathway and therefore assumed a probability of 1 for the yes pathway at branch point 2.

Branch Point 3

Branch point 3 is the probability that FMD infection will be detected before or during the ante-mortem exam, given that the slaughtered animal is FMD infected. This probability is designated f3.

FMD-infected chronic carriers typically display no clinical symptoms and no grossly visible pathology. Therefore, the assessment assumes that ante-mortem examination will not detect FMD-infected chronic carriers and specifies a probability of zero for detection. Because it is possible, however unlikely, that ante-mortem exam might detect FMD infection, the assumption overestimates risk.

Branch Point 4

Branch point 4 is the probability that FMD would be detected during post-mortem exam of a slaughtered animal, given that the animal has FMD and the infection was not detected during ante-mortem exam. This probability is designated f4.

For the same reason as at branch point 3, the assessment assumes that post-mortem examination will not detect FMD-infected chronic carriers and specifies a probability of zero for detection. The assumption, again, overestimates risk.

Branch Point 5

Branch point 5 is the probability that all blood clots, lymph nodes, and bones are removed in compliance with CFR 94.21 (i). This probability is designated f5.

5-1 The head (including pharyngeal lymph nodes), feet, and skin are normally removed from all slaughtered animals. (pers. comm., M. Malik, APHIS-NCIE staff, 1997)

5-2 Residual bone, lymph nodes, and blood clots in exported product would be unacceptable to U.S. purchasers of Argentine beef. Thus, the exporter would not only be in violation of CFR 94.21 but would also likely lose markets in the U.S. Thus it is in

Argentina's self-interest to assure compliance with 94.21 (i). (pers. comm., M. Garcia, APHIS-NCIE staff, 1997)

5-3 Beef that does not comply with 94.21 (i) can be easily detected by simple observation. (pers. comm., M. Garcia, APHIS-NCIE staff, 1997)

Branch Point 6

Branch point 6 is the probability that beef that has not had all bones, lymph nodes, and blood clots removed contains virus, given that the animal from which the beef is produced has FMD and that the infection was not detected by ante-mortem and post-mortem exam. This probability is designated f6.

6-1 It is probable that the parts of a bovine carcass that are most likely to contain virus (i.e., head, feet, and skin) are removed even if not all bones, nodes, and blood clots are removed. (Pers. comm., M. Garcia, APHIS-NCIE staff, 1997).

Because it is not possible to know precisely the parts of a carcass that are required by 94.21 (i) to be removed but have not been removed, a probability of one is assumed. This overestimates the actual risk.

Branch Point 7

Branch point 7 is the probability that the meat is matured to pH 5.8 in compliance with CFR 94.21 (h). This probability is designated f7

7-1 Meat is tested with a pH meter to determine compliance with 94.21 (h). Meat not in compliance after 36 hours may be retested after 60 hours. (CFR 94.21 (h); pers. comm., John Blackwell, 1997)

7-2 "When a muscle is in full rigor, the pH may range from 5.4 to 6.0. After 48 hours storage at temperatures slightly above the freezing point, the pH averages 5.6 to 5.9." (Cottral, Cox, and Baldwin, 1960)

7-3 Maturation is a normal component of beef slaughter and processing in Argentina. It is not done merely to satisfy USDA regulations. (pers. comm., M. Garcia, APHIS-NCIE staff, 1997)

7-4 Routine, periodic inspection by USDA personnel of slaughter plants producing beef for export would include review of beef maturation procedures. (pers. comm., M. Malik, APHIS-NCIE staff, 1997)

Branch Point 8

Branch point 8 is the probability that beef that is not matured to pH 5.8 in compliance with CFR 94.21 (h) is diverted to domestic use in Argentina. This probability is designated f8.

8-1 Carcasses that do not reach the required pH are normally diverted for domestic Argentine use. (pers. comm., M. Malik, APHIS-NCIE staff, 1997)

Branch Point 9

Branch point 9 is the probability that the beef contains FMD virus, given that all bones, blood clots, and lymph nodes have been removed and that the animal was FMD infected and the infection was not detected by ante-mortem or post-mortem exam. This probability is designated f9.

9-1 Ante-mortem and post-mortem exam is likely to detect cattle with acute FMD. (Analysis of BSE Risk Factors in Argentina, http://www.mecon.ar/Agricultura/azseg2.htm, 1997)

9-2 Chronic FMD carrier animals are not likely to be viremic. The most likely anatomic site for FMD virus in chronic carrier animals is the pharyngeal lymph nodes. (Blood and Radostits, 1989)

9-3 Animals slaughtered in compliance with CFR 94.21 (h) will have had pharyngeal lymph nodes removed. (pers. comm., M. Garcia and M. Marolo, APHIS-NCIE staff, 1997)

Branch Point 10

Branch point 10 is the probability that the meat is matured to pH 5.8 in compliance with CFR 94.21 (h). This probability is designated f10.

10-1 Meat is tested with a pH meter to determine compliance with 94.21 (h). Meat not in compliance after 36 hours may be retested after 60 hours. (CFR 94.21 (h); pers. comm., John Blackwell, 1997)

10-2 "When a muscle is in full rigor, the pH may range from 5.4 to 6.0. After 48 hours storage at temperatures slightly above the freezing point, the pH averages 5.6 to 5.9." (Cottral, Cox, and Baldwin, 1960)

10-3 Maturation is a normal component of beef slaughter and processing in Argentina. It is not done merely to satisfy USDA regulations. (pers. comm., M. Garcia and M. Marolo, APHIS-NCIE staff, 1997)

10-4 Routine, periodic inspection by USDA personnel of slaughter plants producing beef for export would include review of beef maturation procedures. (pers. comm., M. Malik and M. Garcia, APHIS-NCIE staff, 1997)

Branch Point 11

Branch point 11 is the probability that beef that is not matured to pH 5.8 in compliance with CFR 94.21 (h) is diverted to domestic use in Argentina. This probability is designated f11.

11-1 Carcasses that do not reach the required pH are normally diverted for domestic Argentine use. (pers. comm., M. Malik, APHIS-NCIE staff, 1997)

Branch Point 12

Branch point 12 is the probability that FMD virus is killed, given that the meat is matured to pH 5.8 and that not all bones, nodes, and clots have been removed. This probability is designated f12.

12-1 Bones, lymph nodes, and blood clots do not normally produce lactic acid post-mortem and therefore the pH of these tissues does not decrease as rapidly as it does in muscle tissues. (Cottral et al, 1960)

12-2 Although not all bones, lymph nodes, and blood clots are removed from the meat, it is likely that most bones, lymph nodes, and blood clots are removed. (APHIS staff estimate)

INPUT VARIABLES

Minimum, most likely, and maximum estimates for the initiating event and probabilities f1-12 are shown in Table 1.

Table 1

**INTRODUCTION OF FMD FROM IMPORTATION OF BEEF FROM ARGENTINA (Chronic Only)
VALUE OF INPUT VARIABLES**

Estimates Of Input Variables		Minimum	MostLikely	Maximum
Initiating event - Number of animals slaughtered per year		200,000	400,000	2,000,000
f1	Animal has FMD given compliance with 94.21 (e)	0.00E+00	0.00E+00	2.00E-07
f2	Meat complies with 94.21 ( )	1	1	1
f3	FMD infection detected by ante-mortem exam	0	0	0
f4	FMD infection detected by post-mortem exam	0	0	0
f5	Meat complies with 94.21 ( )	0.98	0.99	0.999
f6	Meat has FMD virus	1	1	1
f7	Meat complies with 94.21(h) - matured to pH 5.8	0.8	0.9	0.99
f8	Diverted to domestic use	0.95	0.99	0.999
f9	Meat has FMD virus	0.05	0.1	0.15
f10	Meat complies with 94.21(h) - matured to pH 5.8	0.8	0.9	0.99
f11	Diverted to domestic use	0.95	0.99	0.999
f12	Virus killed	0.05	0.1	0.2

MATHEMATICAL MODEL

The probability that a side of beef from a given slaughtered animal has FMD, is not detected by ante-mortem or post-mortem exam, has all bones, nodes, and blood clots removed, has virus, is not matured to pH 5.8 and is not diverted to domestic use (pathway 1) is:

$$f1*(1-f3)*(1-f4)*f5*f9*(1-f10)*(1-f11)*2. \qquad \text{Eqn. 1}$$

The probability that a side of beef from a given slaughtered animal has FMD, is not detected by ante-mortem or post-mortem exam, does not have all bones, nodes, and blood clots removed, has virus, is matured to 5.8, and does not have all virus inactivated by maturation (pathway 2) is:

$$f1*(1-f3)*(1-f4)*(1-f5)*f6*f7*(1-f12)*2. \qquad \text{Eqn. 2}$$

The probability that a side of beef from a given slaughtered animal has FMD, is not detected by ante-mortem or post-mortem exam, does not have all bones, nodes, and blood clots removed, is not matured to pH 5.8, and is not diverted to domestic use (pathway 3) is:

$$f1*(1-f3)*(1-f4)*(1-f5)*f6*(1-f7)*(1-f8)*2. \qquad \text{Eqn. 3}$$

Note that all of the above equations include a multiplier of two due to the fact that every slaughtered animal produces two sides of beef.

The probability formulas in equations 1-3 calculate the probability that a side of beef from a randomly selected bovine in Argentina would be exported contaminated with FMD virus via each of the three identified pathways.

The pathways are mutually exclusive, i.e., any given side of beef exported with FMD virus could only come from one of the three pathways. Examination of the conditions pertaining to each pathway, i.e., bones and nodes removed or not removed, matured to pH 5.8 or not matured, etc. will demonstrate this. Thus, the probability that a given side of beef will contain FMD virus is the probability that it comes from either pathway 1 or pathway 2 or pathway 3, i.e., the sum of the three pathways:

$$\begin{aligned}&\text{Pr (side of beef exported with FMD virus)} = \\ &\text{Pr (pathway 1)} + \text{(pathway 2)} + \text{(pathway 3)} \qquad \text{Eqn. 4}\end{aligned}$$

Equation 4 represents the probability that a side from a randomly selected bovine in Argentina could eventually be exported with FMD virus. The number or frequency of FMD-contaminated sides exported per year is a function of the number of animals slaughtered for export to the U.S.

Many such phenomena are modelled as binomial processes, or ones where there are many "trials", each with the same probability of "success" (which, in this case, means the export of a FMD-contaminated side). A simple example of such a process is the repeated tossing of a coin; the probability of success on a given trial or toss is *p* (equal to 1/2) and the number of trials is termed *n*.

Similarly, the export of FMD-contaminated sides of beef from Argentina can be modelled as a binomial process where:

n = number of sides exported
= number of animals slaughtered * 2;

p = probability that any given side is exported with FMD virus (from equation 4); and

x = number of FMD-contaminated sides exported in one year.

The binomial model allows computation of the probability of exporting a given number of FMD-contaminated sides per year:

$$Pr(x=0) = (1-p)^n$$

$$Pr(x=1) = np(1-p)^{n-1}$$

$$\begin{aligned} Pr(x>=1) &= 1 - Pr(x=0) \\ &= 1 - (1-p)^n \end{aligned}$$

The average, i.e., mean, number of FMD-contaminated sides exported per year is the probability that a given side is contaminated multiplied by the number of sides exported:

$$\text{Mean } x = n*p$$

In cases where the mean value of x is less than one, the reciprocal or inverse of n*p indicates the mean frequency with which a FMD-contaminated side is exported. Thus, if n*p = .01 contaminated sides per year, then:

$$1/n*p = \text{mean years per contaminated side} = 100$$

This result, as well as being intuitive, is verified by its equivalence to the mean of the negative binomial distribution modelled for the number of "failures" (i.e., sides of FMD-free beef) expected before one "success". The following section will demonstrate this for Argentine beef.

Uncertainty in the probability values was addressed by using minimum possible, most likely, and maximum possible values for each probability and for the number of animals selected for export and triangular probability distributions. Calculations were performed using Monte Carlo simulations and @Risk software.

RESULTS

Probability that Individual Side of Beef Has Live FMD Virus

The probabilities for randomly selected sides of beef being exported with live FMD virus from pathways 1,2, and 3 are represented by the probability curves in Figure 2. The spread of each curve indicates the range of uncertainty for each parameter value and the height of the curves indicates our confidence in a particular value on the x-axis. Each distribution has about the same dispersion, about 5 orders of magnitude between the minimum and maximum values (see Table 2 for summary statistics for selected model outputs). The expected values (mean or average value) for the probability that a randomly selected side of beef would be exported with live FMD virus are quite small: 7.1×10^{-12} for pathway 1; 3.5×10^{-10} for pathway 2; and 6.9×10^{-13} for pathway 2. The sum of these distributions is a distribution with mean of 3.5×10^{-10}, essentially identical to that for pathway 2 (Figure 3). Pathways 1 and 3 contribute negligibly to the sum of the three probabilities. The probability distribution shown in Figure 2 will be noted as p' in the following section.

Annual Probability of Exporting FMD-Contaminated Sides of Beef

Treating the annual export of sides of beef as a binomial process with

n = number sides exported annually
= Number of animals (Initiating Event) * 2
p = probability a side will have live FMD = p'

allows the calculation of the probability of one or more FMD-contaminated sides being exported in one year:

$$1 - (1-p')^n$$

where p' and n are random variables as described. This quantity is also a random variable or distribution and is shown in Figures 4a and 4b. The x-axes in both figures utilize log scales to better display the distribution; the nominal values that correspond to these log values equal 10 exponentiated to the appropriate value. For example, where the log scale indicates -3, the nominal value is 10^{-3} or 0.001. The mean or average for the distribution is $10^{-3.27727}$ or 5.4×10^{-4} or 0.00054. This indicates the mean frequency of infected sides exported per year is 0.00054. This measure can be converted to the mean number of years expected before export of one infected side by using the inverse or reciprocal of this rate:

1/0.00054 contaminated sides/year =
1 year/0.00054 contaminated sides =
1,862 years per exported contaminated side.

Thus, on average we would expect 1,862 years of FMD-free exports before export of an FMD-contaminated side. The distribution for this variable is shown as an inverse cumulative distribution (Figure 5a) and as a typical probability curve (Figure 5b). The expected value for the distribution is $10^{3.2725}$ years (1,873 years) so the expected frequency of FMD-contaminated sides of beef is one in 1,873 years. The 5% and 95% fractiles on the inverse cumulative (or exceedence) distribution are 331 and 20,417 years, respectively. This means there is only a 5% chance the value my be less than 331 years per FMD export and a 5% chance that it may be greater than 20,417 years per FMD export.

The validity of this approximation is demonstrated by utilizing the negative binomial distribution. The negative binomial computes the probability of having *x* failures before getting *s* successes in total where the probability of success on a given trial is *p*. Defining "success" as the export of 1 or more FMD-contaminated sides in one year, then "failure" is the export of zero FMD-contaminated sides in one year. The mean of the negative binomial distribution is:

$$\frac{s(1-p)}{p}$$

so substituting the appropriate values for

p = pr(exporting FMD-contaminated side per yr)
s = 1 (the number of successes or FMD exports)

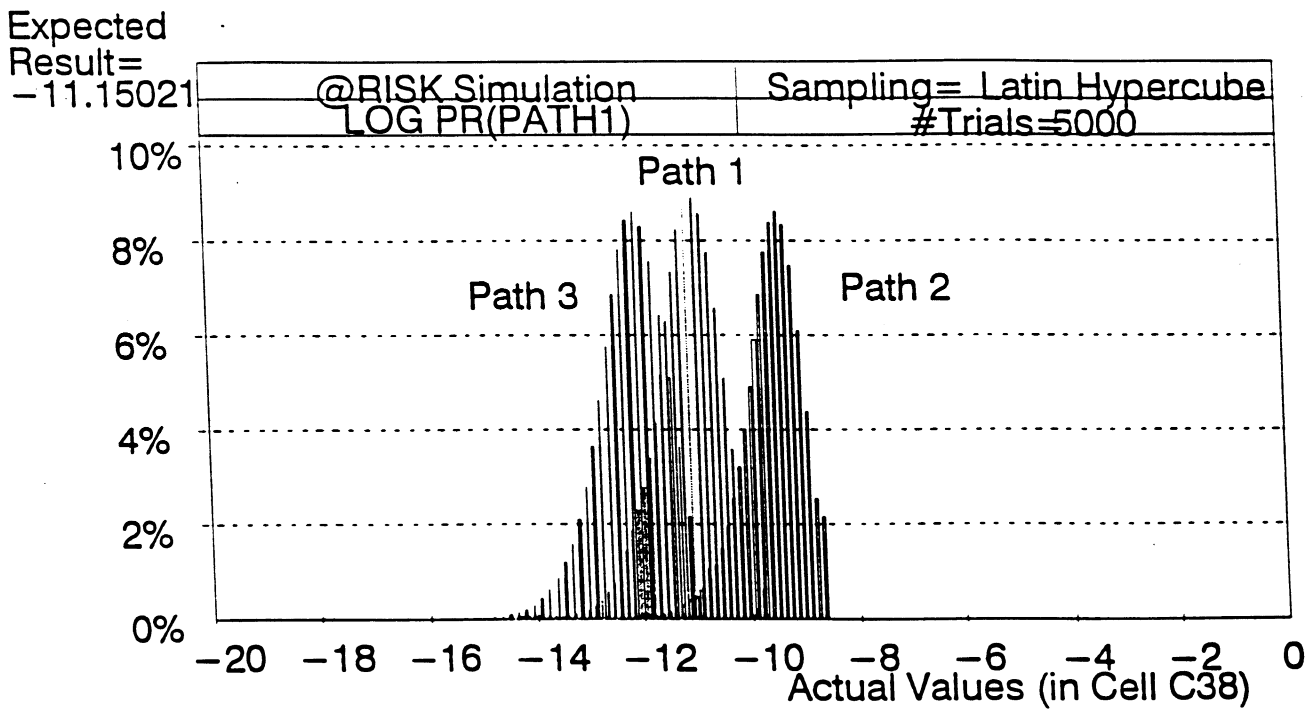
yields the average number of years to get one FMD-contaminated side:

$$\frac{1(1-0.0053372)}{0.00053372} = 1{,}872 \text{ years.}$$

Thus the exact figure from the negative binomial differs, in relative terms, from the approximation using the inverse expected value by less than 1% (10/1862 = 0.005).

Figure 2

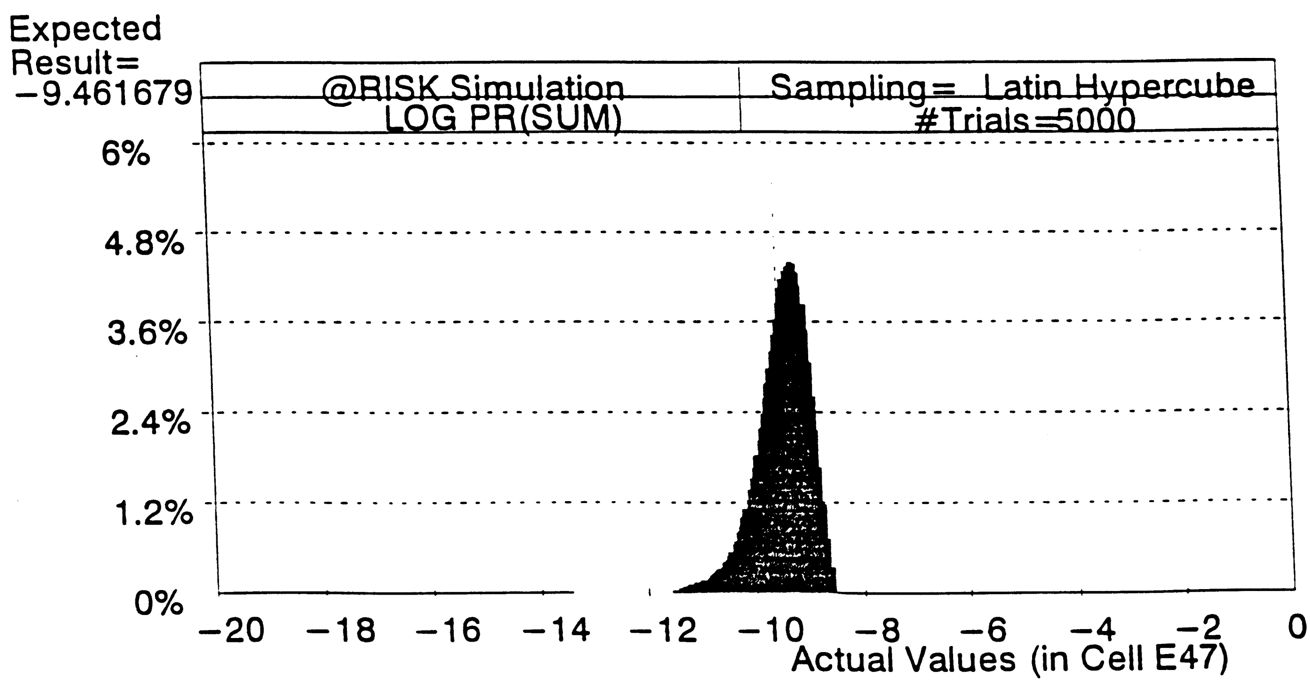
Probability of side of FMD–contaminated beef exported through various pathways.



Log of Probability

Figure 3

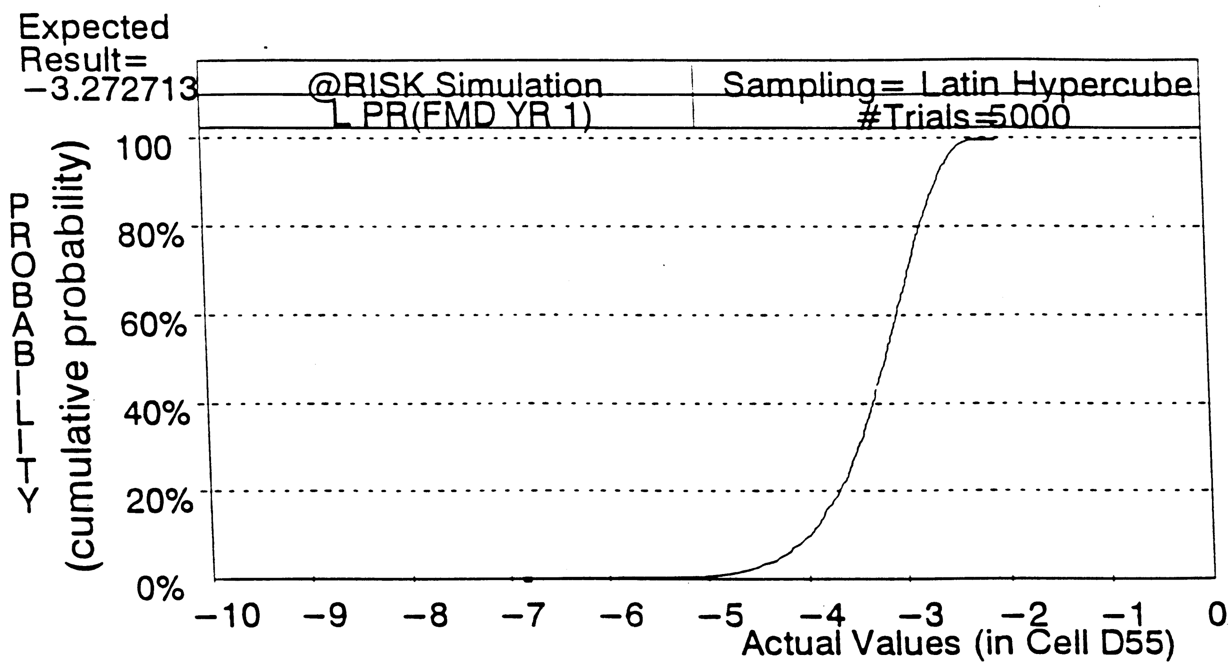
Sum of probability of side of FMD–contaminated beef exported through various pathways.



Log of Probability

Figure 4a

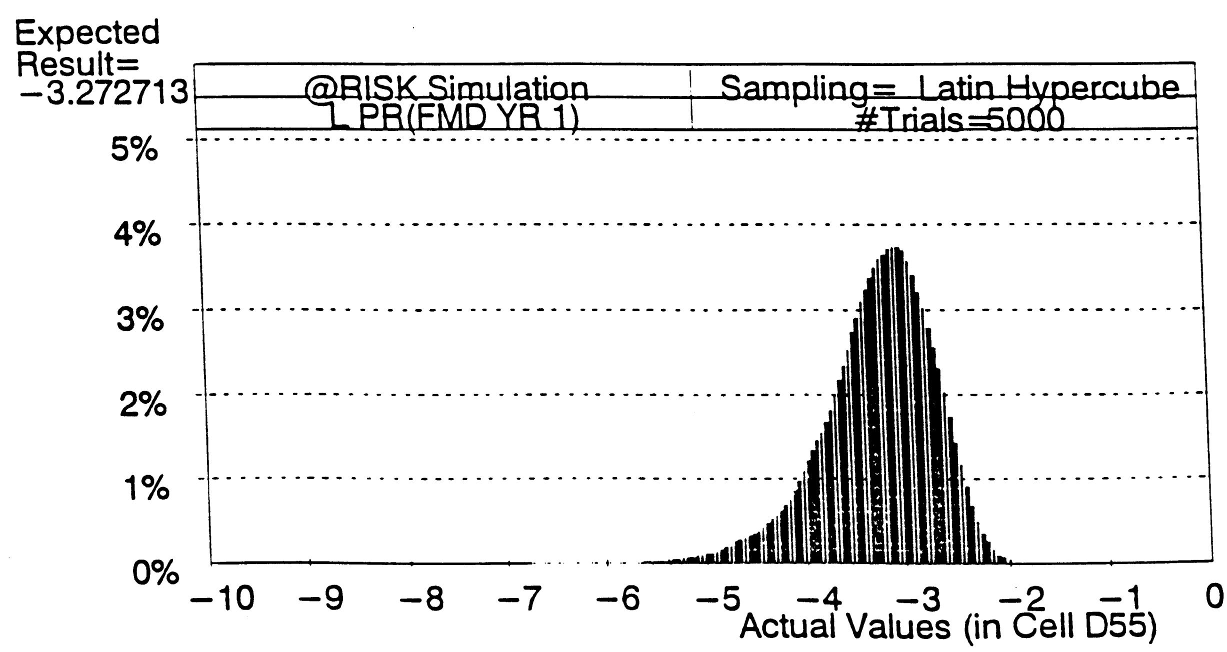
Cumulative distribution for annual probability that one or more FMD–contaminated sides of beef are exported in one year.



log of annuall probability of >= 1 FMD+ side exported
(Sum of all pathways)

Figure 4b

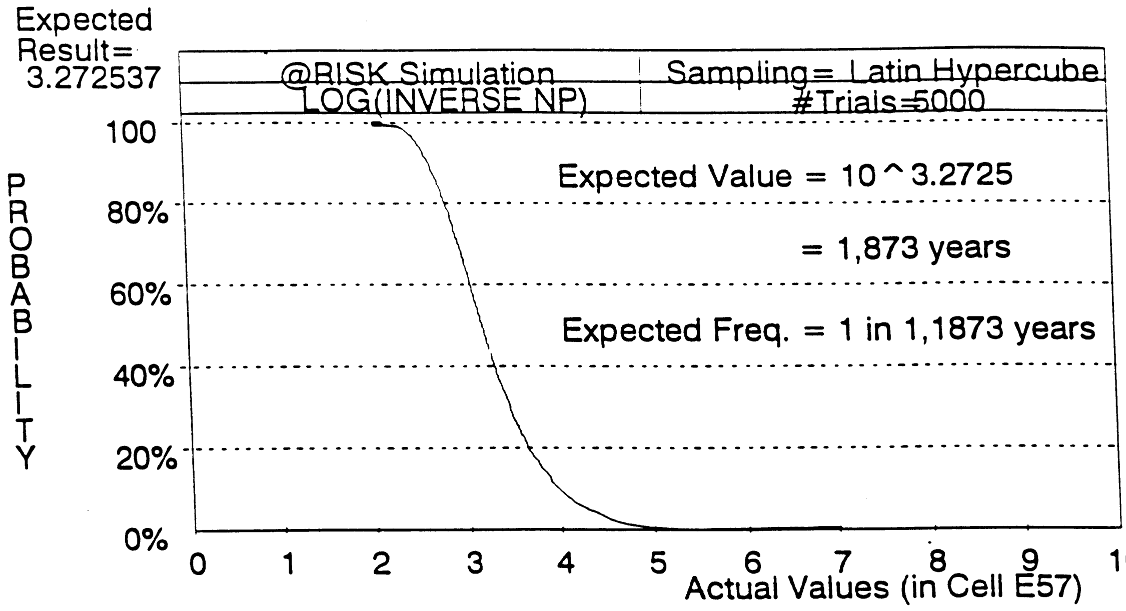
Distribution for annual probability that one or more FMD–contaminated sides of beef are exported in one year.



log of annuall probability of >= 1 FMD+ side exported
(Sum of all pathways)

Figure 5a

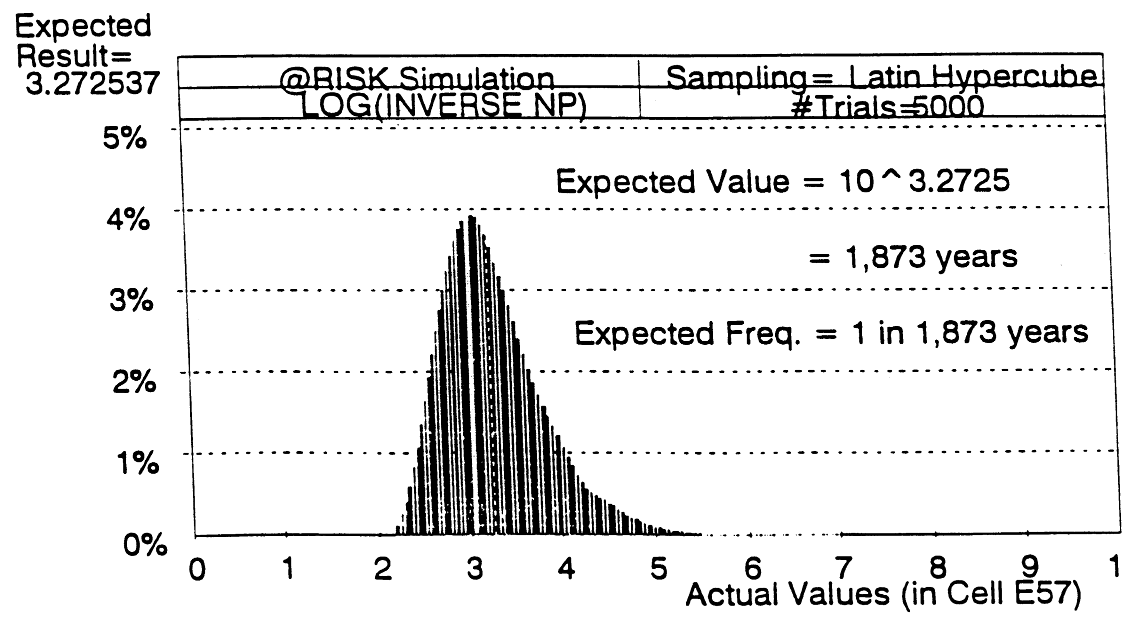
Exceedence distribution for frequency of FMD–contaminated beef exported to United States from Argentina. 1/



Log of Years 2/

Figure 5b

Probability distribution for frequency of FMD–contaminated beef exported to United States from Argentina. 1/



Log of Years 2/

1/ Exceedence graph illustrates the likelihood that variable will exceed the x–axis value; for example, there is 40% chance the inverse of the frequency of FMD–contaminated beef is exported exceeds 10^3.27 or 1,873 years. Thus there is 40% probability that FMD–contaminated beef would be exported less frequently than 1 in 1,873 years.

2/ Values on x–scale indicate log of years, e.g., "3" indicates 10^3 or 1,000.

Table 2

Simulation Statistics for Model Variables for Estimating Frequency of Exporting FMD–Contaminated Beef from Argentina to the United States. 1/

Statistic 2/	Pathway 1 log	Pathway 1 nominal	Pathway 2 log	Pathway 2 nominal	Pathway 3 log	Pathway 3 nominal	Sum of Pathways log	Sum of Pathways nominal
mean	–11.15	7.1E–12	–9.46	3.5E–10	–12.16	6.9E–13	–9.46	3.5E–10
minimum	–14.75	1.8E–15	–13.42	3.8E–14	–16.65	2.2E–17	–13.4	4.0E–14
maximum	–9.76	1.7E–10	–8.56	2.8E–09	–10.76	1.7E–11		1.0E+00
X_5%	–12.24	5.8E–13	–10.47	3.4E–11	–13.31	4.9E–14	–10.45	3.5E–11
X_95%	–10.35	4.5E–11	–8.84	1.4E–09	–11.28	5.2E–12	–8.83	1.5E–09

Statistic 1/	Pr(FMD export in 1 yr) log	Pr(FMD export in 1 yr) nominal	Inverse of Expected Value of Distribution for 1 Year log	Inverse of Expected Value of Distribution for 1 Year nominal	Average Frequency
mean	–3.27	5.4E–04	3.27	1,862	1 in 1,862 years
minimum	–7.03	9.3E–08	2.01	102	1 in 102 years
maximum	–2.01	9.8E–03	7.03	10,715,193	1 in 10,715,193 years
X_5%	–4.23	5.9E–05	2.52	331	1 in 301 years
X_95%	–2.52	3.0E–03	4.31	20,417	1 in 20,417 years

1/ Pathways refer to spefic routes of entry as described in the scenario tree (Figure 1).
2/ X_5% refers to the 5% fractile of the cumulative distribution; X_95% refers to the 95% fractile of the cumulative distribution.

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